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Prosthetic Hand

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Biomimetic Prosthetic Hand

Honors Research Project Report

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Abstract

This novel trans-radial prosthetic hand is an integrative design between biomimicry and traditional robotic prosthesis while using the technology of 3D printing. An amputee's [Redacted] prosthetic hand to [Redacted]. Additionally, [Redacted] and 3D printed using a material that [Redacted]. Tendons were modeled as [Redacted] that were threaded through the fingers and connected back to [Redacted]. To provide a custom and precise fit for the patient, a [Redacted].

Description of Problem

When a medical professional is fitting a patient for a prosthesis, a plaster mold is normally taken of the residual limb to provide a proper fit to model the socket after. A few issues with this methodology are that it is quite time consuming and uncomfortable for the patient to sit and let the plaster dry around their limb. Additionally, these molds are usually taken quite recently after amputation and a lot of times the limb is still swollen and can cause an inaccurate fit once the socket is casted around the plaster [1]. Another difficulty is that some prosthetic devices require a significant learning curve of how to adopt this new limb to do the same job as their original limb.

Therefore, we decided to create a biomimetic approach to solve these problems. First, no molding is required to be able to create a perfect fit for the patient's residual limb. The premise was to use a [Redacted]. Additionally, the structure of this prosthetic hand is made to [Redacted]. This process minimizes the learning curve it would take for the patient to adapt to this new hand since it is modeled after [Redacted]. Theoretically, the hand is designed to move and function similarly to that of a normal hand because we preserved [Redacted] which is contrary to most available prosthesis today.

Another goal of this design was to use specific materials that could be used for 3D printing that [Redacted]. This design would help prevent the phantom-limb feeling that some patients report feeling when their prosthetic is drastically different from the size or weight of their original limb. The outcome of this work would allow prosthetics to have a more humanistic design that can be easily manufactured through the 3D printing process to be tailored to both the shape of the residual limb as well as match the dimensions of the opposing limb. The design of prosthetics in the future could evolve to have more realistic features and maybe even start to incorporate human tissue into the design. The use of 3D printing to manufacture prosthetics would allow manufacturers to reduce cost, making them more affordable and accessible [2]. With the 3D printing technology, the customization of the prosthetic becomes more accessible as well, but with increased cost.

Background

In the United States 50,000 people receive amputations each year. Of those, 600 have wrist and hand amputations [3]. A trans-radial amputation is a type of wrist and hand amputation where the amputation is made at the arm below the elbow, at some point on the radius, leaving the elbow joint intact. A trans-radial prosthesis is an artificial, wearable limb that provides functionality and/or appearance of the human wrist and hand [4].

Prostheses can be classified into three categories: passive, body-powered, and active. Passive prostheses do not move and are generally used for the appearance aspect of having an artificial limb but are not functional. Body-powered prostheses move with energy input from the user to create manual motion. Active prostheses are equipped with sensors and motors to provide electrical finger and wrist motion, commonly with a mechanical feedback system. Current active prostheses available include the Hero Arm, the LUKE arm, the BeBionic Hand, and the Taska Hand. These prostheses use myoelectric sensors and motors to provide the motion and function of a human hand. Of these active prostheses, only the Hero Arm is manufactured using 3D printing, the rest are made via conventional means. The greatest advantage of 3D printing in this context is the ease of manufacturing custom prostheses. It eliminates the need for custom tooling and tooling changeover as dimensional adjustments can simply be made in the model prior to 3D printing, allowing for cheaper and faster manufacturing.

Design Requirements

Initial background research of clinical issues involving previous prosthetic wrists were conducted alongside interviewing a client in order to generate customer requirements. The customer requirements for this project emphasized [Redacted]. The main goal was to be able to develop a [Redacted]. It was vital to understand the user's needs and wants for this design project to set the importance of each objective. Engineering requirements were derived from the customer requirements which allowed for target values and verification methods to be set. The target values drove our material selection for our major component designs and allowed us to select the best approach for each engineering requirement. Extensive research to find adequate materials to fit the requirements along with patent searches took place to ensure the authenticity of our product.

After compiling our research on human tissues, we determined the properties that were necessary to compare for our material search for 3D printing filaments. The key characteristics were [Redacted]. All these specifications were documented in our Quality Functional Deployment (QFD) and used for traceability when finding adequate filament materials. Our findings led us to use two differing [Redacted] due to its strength and [Redacted].

Once our materials and components were identified, the process of [Redacted] and generating their individual [Redacted] began. We utilized [Redacted] to isolate the different segments in the [Redacted]. These layers were [Redacted] to be manipulated into our design aspect of the project. Once the hand was properly [Redacted]. As shown in Figure 1, this provided a proper avenue for the [Redacted], providing flexion and extension to the hand. Each [Redacted]. Similarly, the [Redacted].

Figure 1: [Redacted]

Aside from creating functionality in the hand, the fit of the socket was just as important. Similarly, to the deconstruction of the hand [Redacted], the residual limb was also deconstructed. The [Redacted] was isolated and used to create a [Redacted], as shown in Figure 2. A [Redacted] from the residual limb [Redacted]. Additionally, the design incorporated the [Redacted] being mounted to the [Redacted]. After verification of the [Redacted], those actuators would have [Redacted] improve stability and reduce overall size of the prosthetic.

Figure 2: [Redacted]

When the individual component designs were finalized, the arm was completely modeled together. Each [Redacted] had to be taken into account for the [Redacted]. After each file was isolated for their [Redacted]. This program communicated with the [Redacted]. The [Redacted] needed to be designated to a specific [Redacted] to provide [Redacted]. The [Redacted] was printed using [Redacted] due to its [Redacted] and was modeled around the [Redacted]. Finally, the [Redacted] were printed with [Redacted] to provide a [Redacted]. All models were compiled together to create the final drawing, as seen in Figure 3.

Figure 3: [Redacted]

Future Steps

Due to the impact that COVID-19 has had on our community, we were unable to finish prototyping and could not run our design through our verification protocols to create design revisions. Our next steps in the process were to finish 3D printing the prototype of the hand to be able to [Redacted]. First, the fit of the socket on the patient would be checked to verify that the [Redacted]. Then we would verify the [Redacted]. The current attachment design with the use of [Redacted] was our preliminary design that needed verification to provide adequate feedback. Once attachment points were finalized, we could then analyze the flexion of the hand and ease of usability. By manually testing the flexion of the fingers and then verifying the flexion with the use of the [Redacted], we would validate the design of the hand and show proper movement of the finger and wrist joints. The next step would be to program the [Redacted] to different length settings to provide different [Redacted]. A personal goal of the team, that was out of the scope for this project, was to be able to create a [Redacted]. By utilizing [Redacted] embedded in the [Redacted], the signals would be relayed to the [Redacted] to create human movement. Our plan was to complete this project to allow for another design team to pick up where we left off and be able to incorporate a system for electrical signal processing.

Academic Impact

The Honors Research Project is an integral way of combining undergraduate experiences and knowledge to research. This project allows the engineer to relate what they have learned into practical concepts and potentially industry knowledge. The Food and Drug Administration (FDA) design process is used at every medical device company and is a major part of the engineering world in general [5]. It was very beneficial for the students to conduct an Honors Research Project because it exposes one to the challenges and difficulties in industry. The importance of engineering in industry is highlighted in the project and allows students to understand how a single mistake can be detrimental to final results of a project. It also teaches the importance of following a process when trying to create a new product to keep traceability.

The nature of developing a novel [Redacted] compared to only a design modification from a pre-existing prosthetic is more rewarding. By working on a completely new idea it allows one to understand the design process at a much more detailed level compared to only a single modification. It encourages more collaboration and brainstorming among each student. Teamwork is a skill that is not taught in any core engineering class but is one of the most important skills to develop. This project pushed our team to develop these social skills in order to reach project objectives. Technical coursework allowed us to sufficiently complete the project as well. Certain courses such as Human Anatomy & Physiology, Biomedical Computing, Biomedical Engineering Tools, Statics, and Dynamics were beneficial. Software like MATLAB and SolidWorks were learned in these classes which were used extensively in the project. Courses like Human Anatomy and Physiology gave background knowledge to allow us to understand the clinical issue at a higher level and apply that knowledge to engineering principles we learned in our Statics, Dynamics, and Physics courses. The project forced us to use the technical aptitude developed over the years and apply them to a real-life engineering problem.

The team struggled throughout the project but gained valuable knowledge from failures and successes. One lesson that was understood quickly was the ability to work in ambiguity. The Honors Research Project's structure is purely created from what the student thinks the best approach would be. This is similar to industry where solving a problem can be approached in many different ways and there may be more than a single correct answer. Planning and organizing a project were another main take away from the experience. The design process was emphasized greatly and what expectations to have during each stage. The team approached each stage as a lesson to strengthen individual skill sets and the project overall added value to the undergraduate experience.

Conclusions

The goal of this research project was to create a novel, [Redacted] prosthetic that conformed to the patient's [Redacted]. Another goal was the physiological range of motion and strength, that was set to achieved by being manufactured using 3D printing. A novel way of generating prosthesis models was developed to conform to [Redacted] while being [Redacted]. The models were built in a way such that the entire prosthesis could be printed [Redacted], using [Redacted]. This was done to minimize assembly time as well as create structures that would be impossible using conventional means. The final design of this device required more time and testing to be accurately executed, but the current plan is sufficient enough to prove the accuracy of generating a prosthetic limb from [Redacted].

References

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Appendix

Table 1: [Redacted]